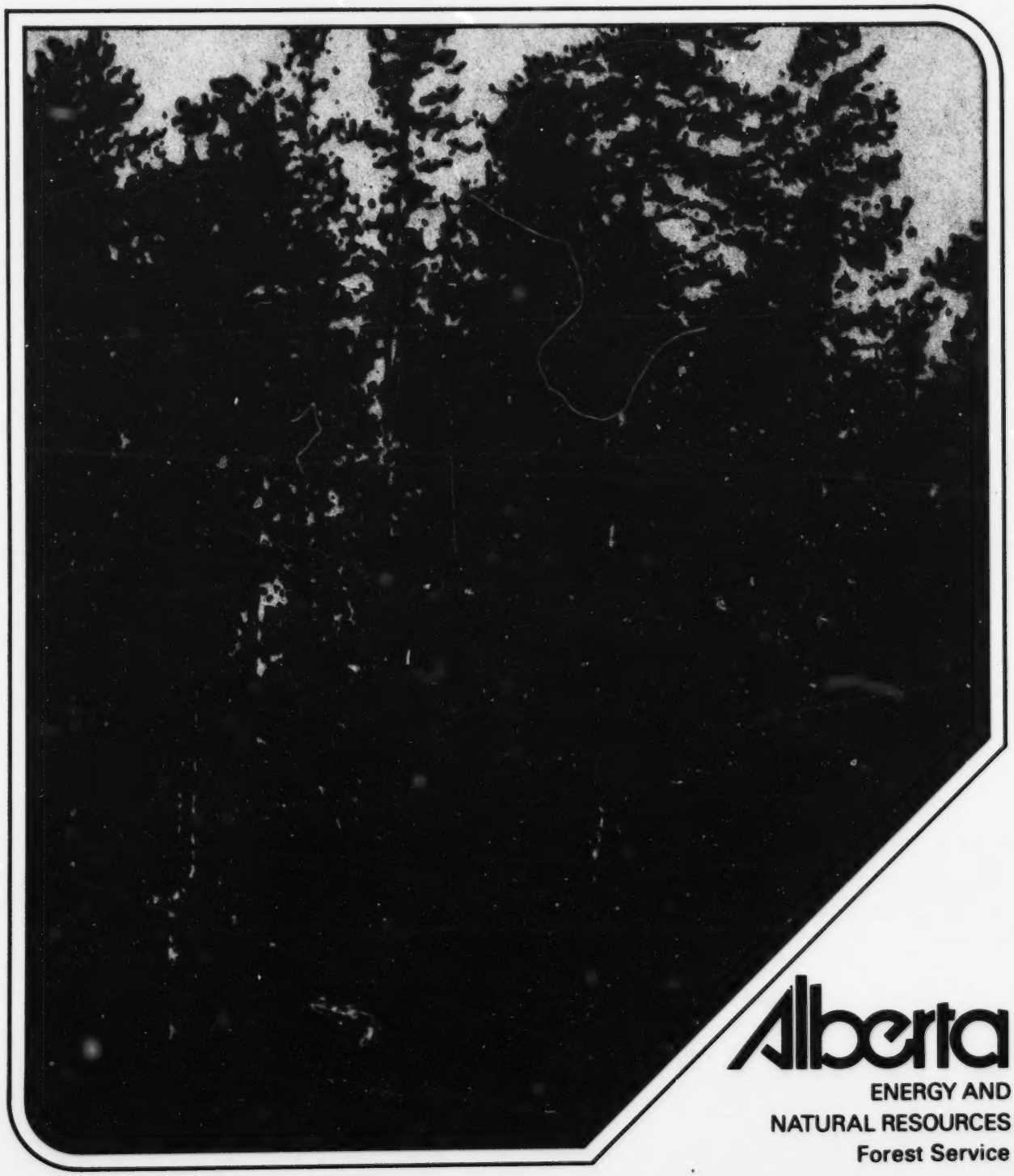
Role of Topsoil, Fertilizers and Companion Crops in Revegetation of Two Severe Sites in the Alberta Foothills and Mountains



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ROLE OF TOPSOIL, FERTILIZERS AND COMPANION CROPS IN REVEGETATION OF TWO SEVERE SITES IN THE ALBERTA FOOTHILLS AND MOUNTAINS[1]

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INTRODUCTION

The influence of fertilizer or topsoil in revegetation of a drastically-disturbed site has most often rated high as a factor for reclamation success in field trials and under operational reclamation situations in Alberta's Rocky mountains and Foothills region. In exposed high-elevation environments these two factors are as important as climatic factors in limiting plant growth and hence in cover establishment. The role of fertilizers is in the improvement of the fertility of a site; that of topsoil includes improvement in fertility as well as in the physical properties of the soil which are important for good growth of plants. In the harsh environments under discussion, topsoiling and fertilization play significant roles in improving the microsite to increase the chances of revegetation success.

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[1]A paper presented at the Workshop on Revegetation Methods in the Mountains and Foothills. April 30 and May 1, 1984, Edmonton, Alberta, Canada.

In field reclamation trails, grass-legume mixture ground covers have shown responses to fertilizers. Often, if the objective was an initial site stabilization to encourage the ingress of native vegetation or to allow for the later successful establishment of woody species, the problem has been in the management of the dense plant cover due to fertilizers.

Our experience in Alberta's alpine and subalpine zone generally shows that native grasses seeded on disturbed sites do not develop a ground cover as fast as cultivated grasses and legumes. In a situation whereby a rapid, erosion-controlling plant cover is the primary objective, and where native grasses are the primary plant cover desired for some specified reasons, seeding the faster growing cultivated species as companion crops appears the best choice in achieving both objectives.

The trials reported have involved other individuals who are still employed by the Forest Service or worked with the Service sometime between 1978 and now. This paper is therefore a summary of portions of the trials, with the objectives of: (a) evaluating the effects of fertilizers on the establishment and growth of native grass seed mixtures and cultivated grass-legume seed mixtures, (b) comparing the difference in plant cover establishment between overburden or mine spoil, and the same two waste materials topdressed with mineral soils, and (c) evaluating the effects of companion crops on native grass seed mixtures in plant cover establishment.

EXPERIMENTAL SITE

Six of the eight trials discussed in this paper are located on an abandoned mine near Cadomin in west-central Alberta, and two are located at Adanac in the south-western part of the province near Blairmore. At each site, one set of the trial was located on the raw overburden or spoil and the other on overburden or spoil which was topdressed with mineral soil to an average depth of 20 cm.

The two locations were abandoned minesites, and although far from each other, experience similar climatic and environmental conditions. The Cadomin site is described elsewhere in these proceedings by the same author. Adanac is an abandoned strip mine on Hastings Ridge in the Front Ranges 12 km south of Blairmore. The mine is believed to have been abandoned in the early 1950's. The area is classified in the subalpine forest region, and the site is at an elevation of 1 895 m. Site conditions in terms of precipitation, exposure and windspeeds are similar to those at Cadomin but chinooks are more frequent and last longer. The temperatures at Adanac are slightly higher than at Cadomin, but extremes are similar.

REHABILITATION METHODS

A. Fertilizer Treatments

The trials were laid out at Cadomin in June 1978, on overburden and on spoil. They were done separately on the raw materials and on the raw materials topdressed with mineral soil.

1. Cultivated Seed Mixture Trail

The trials were laid out on the raw spoil and on the same spoil which was topdressed with mineral soil to an average depth of 20 cm. They were laid out as a randomized block design in three replications and consisted of five fertilizer rate and four seeding rate treatments. The seed mixture was composed of creeping red fescue (40% by weight), white clover (12%), Timothy (24%), and Canada bluegrass (24%). The seed and fertilizer were both broadcast and raked into the soil.

2. Native Grass Mixture Trial

The trials were laid out on the raw overburden and on the same overburden topdressed with mineral soil to an average depth of 20 cm. Both were laid out in a randomized complete block design with three replications. Three fertilizer rates were tested along with two other factors, seeding rate and companion crops. The native grass seeding mixture was composed of equal numbers of seeds of Agropyron trachycaulum (69% by weight), Festuca saximontana (15%), Poa interior (8%) and Trisetum spicatum (8%).

B. Companion Crop Treatments

The trials were laid out on overburden in two separate studies in 1978 and 1979 at Cadomin, and in a single study in 1979 at Adanac. The trials were repeated at both locations on overburden topdressed with mineral soil. Native grass seed mixes were used in all six trials.

The 1978 trials at Cadomin had the following companion crop treatments: barley (20 kg/ha); red clover (3 kg/ha); cultivated species mix

(creeping red fescue, 40% by weight; white clover, 12%; timothy, 24%; Canada bluegrass, 24%; seeded at 15 kg/ha); and a control. The rest of the treatments and other details of the trials are the same as the fertilizer treatments for native grass mixture trials described above.

The trials laid out in 1979 in both locations were designed to evaluate five companion crops and four native grass seed mixtures. The treatments were replicated three times in a randomized complete block design. Companion crop treatments applied at 5 kg/ha were: meadow foxtail; Timothy and white clover; creeping red fescue and alsike clover; perennial rye grass; and a control. The plots were raked before and after hand seeding and fertilizing with urea, 10-30-10 and potassium chloride to provide 80 kg N, 60 kg P and 60 kg K/ha.

RESULTS AND DISCUSSIONS

Overburden and Spoil Properties

Soil analyses results (summarized in Tables 1 and 2) show that the spoil, overburdens or mineral soils used for topdressing cannot be considered fertile materials for optimum plant growth. This implies that responses to fertilizers are expected to be high, assuming the fertilizer nutrients can be retained without being mostly leached out of the highly porous overburden and spoil. The overburden and the spoil at Cadomin are alkaline, and the overburden at Adanac is very acid in reaction, so that they can significantly affect the growth of sensitive plant species.

TABLE 1

SOME PROPERTIES OF THE SPOIL, OVERBURDEN AND MINERAL SOIL USED FOR TOPDRESSING AT CADOMIN*

	CULTIVATED SPECIES		NATIVE GRASS SPECIES	
	SPOIL	MINERAL SOIL	OVERBURDEN	MINERAL SOIL
pH	8.8	6.9	8.9	6.5
Ec (mS/cm)	0.3	0.1	0.3	0.1
AVAIL. NUTRIENTS (ppm)				
NH_4-N	5.6	4.5	3.7	4.1
NO_3-N	0	1	0	0
P	0	10	0	12
K	186	214	235	219
TOTAL N (%)	0.13	0.07	0.03	0.07
T.E.C. (me/100g)	6.6	13.2	6.4	12.7

* STUDIES STARTED IN 1978

TABLE 2

SOME PROPERTIES OF THE OVERBURDENS AND MINERAL SOILS USED FOR TOPDRESSING*

	CADOMIN		ADANAC	
	OVERBURDEN	MINERAL SOIL	OVERBURDEN	MINERAL SOIL
pH	8.4	7.1	4.6	6.4
Ec (mS/cm)	0.2	0.2	0.2	0.2
AVAIL. NUTRIENTS (ppm)				
NH_4-N	1.9	2.3	7.2	8.9
NO_3-N	1	1	0	3
P	1	2	19	11
K	89	71	43	209
TOTAL N (%)	0.06	0.08	0.27	0.27
T.E.C. (me/100g)	9.9	15.4	13.9	27.7

* (STUDIES STARTED IN 1979)

The high total nitrogen level in the spoil is attributable to the high total level of the element in the coal in the spoil (see paper by the same author elsewhere in these proceedings). The overburdens at the two locations are very similar in their physical characteristics; the characteristics of the overburden and those for the spoil are discussed by the same author in another paper in these proceedings.

Fertilizer Effects

Cultivated Grass-Legume Cover

Effects of fertilizers on the cultivated grass-legume mixture on the percentage of plant cover are shown in Figure 1. Dry matter yields are shown in Figure 2. Generally, both percentage of cover and dry matter yields increased as the rate of fertilizer application increased; the trends were still maintained even after annual fertilization was stopped. Both percentage of plant cover and dry matter production (shown in Figures 3 and 4) declined in 1982 as a result of the stoppage of annual fertilization of the fertilized treatments and to a more marked degree in 1983. (Percentage of plant cover in this context refers to the above-ground living plant parts. This tends to underestimate percentage of cover because accumulated thatch is essentially ignored.) Although percentage of cover in the first two seasons was generally greater on the raw spoil than on topdressed spoil, dry matter production was lower on the raw spoil. The odd relation between dry matter production and percentage of

Figure 1: FERTILIZER EFFECTS ON PLANT COVER FOLLOWING FOUR SEASONS (1981) OF FERTILIZATION, AND TWO SEASONS (1983) AFTER FERTILIZERS WERE WITHDRAWN.

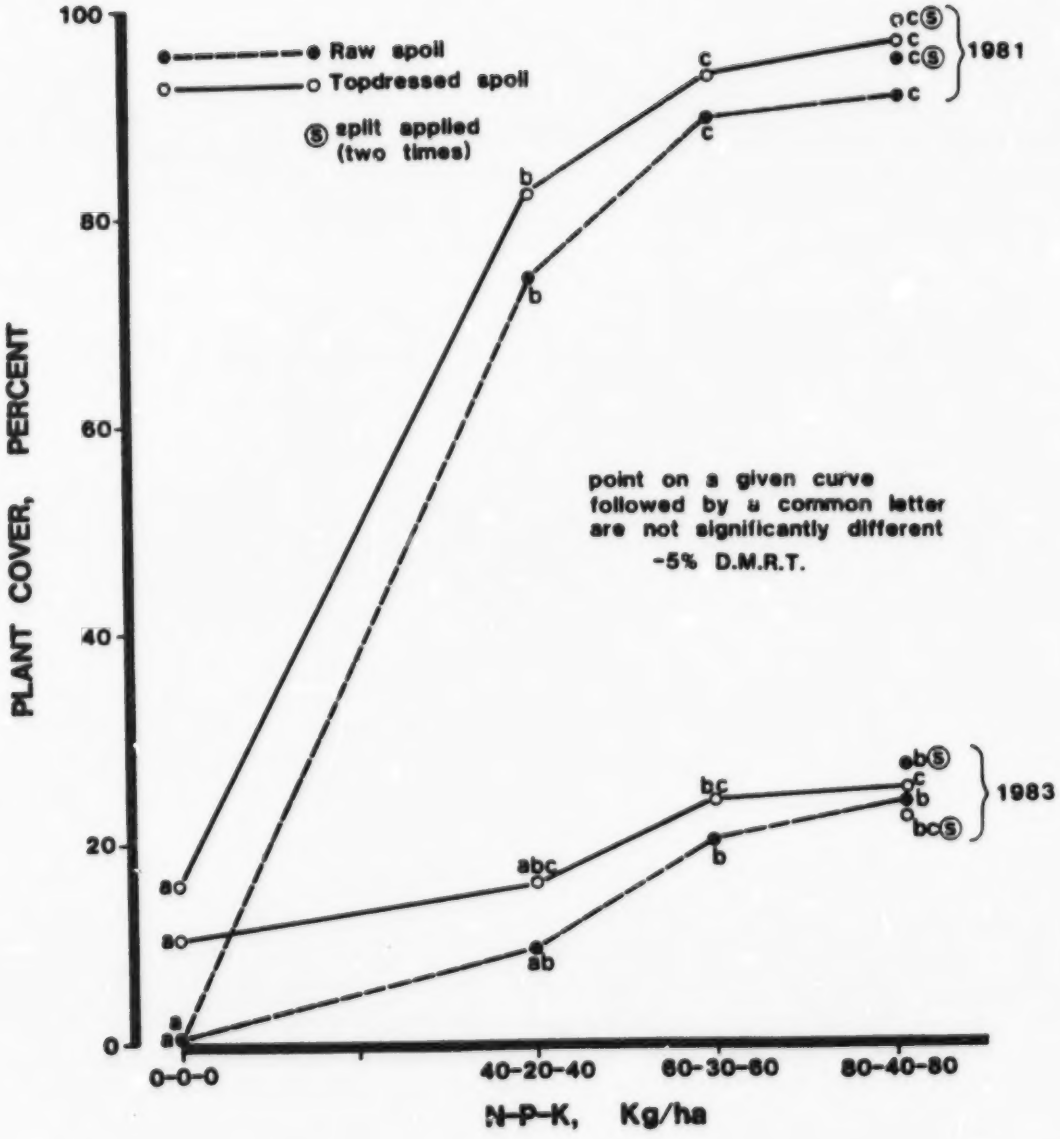


Figure 2: DRY MATTER YIELDS FOLLOWING FOUR SEASONS OF FERTILIZATION AFTER SEEDING TO 1981 AND TWO SEASONS (1983) AFTER FERTILIZERS WITHDRAWN.

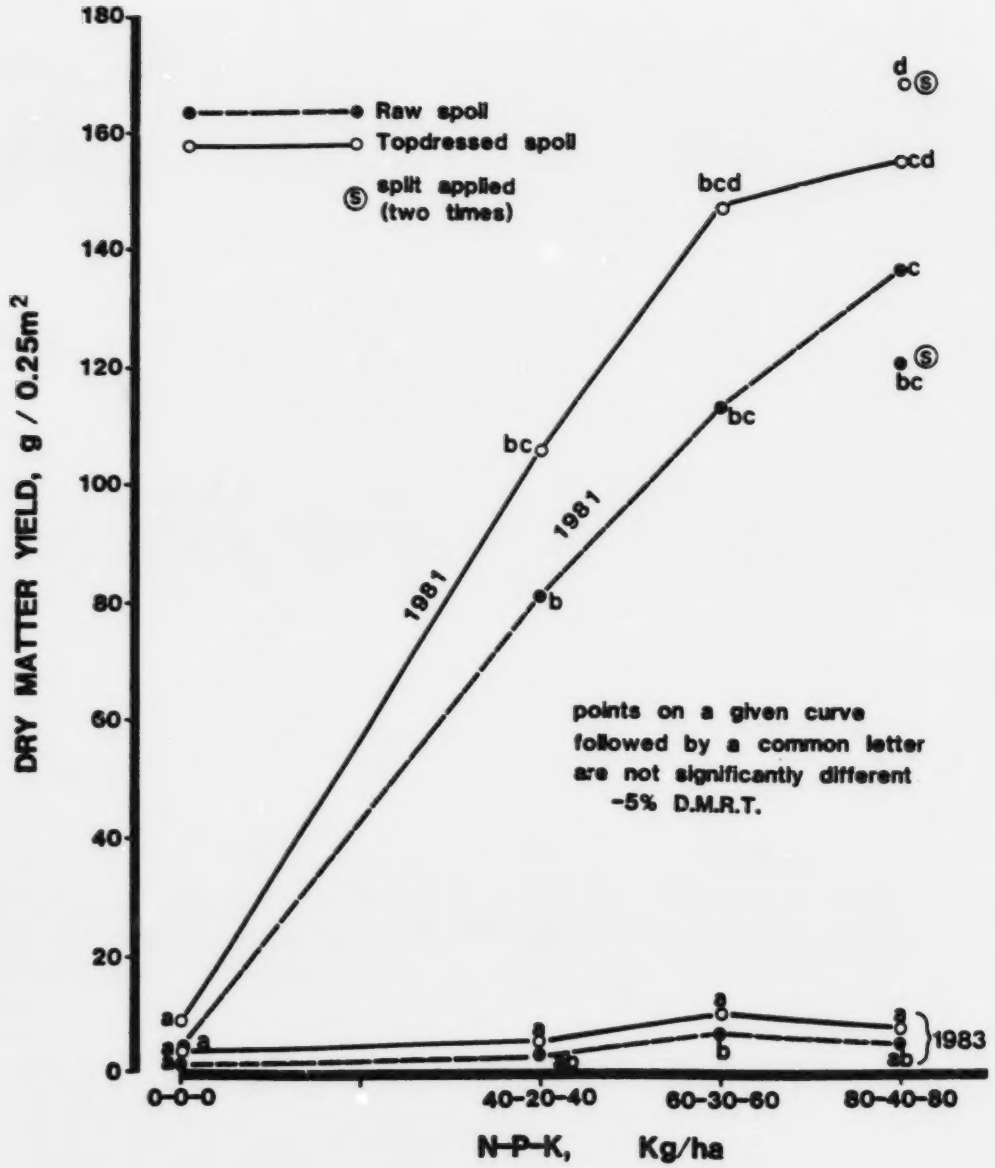


Figure 3: CHANGES IN PLANT COVER BETWEEN SEEDING AND 1983 (TWO SEASONS AFTER FERTILIZERS WERE WITHDRAWN - FOR 60N-30P-60K Kg/ha.)

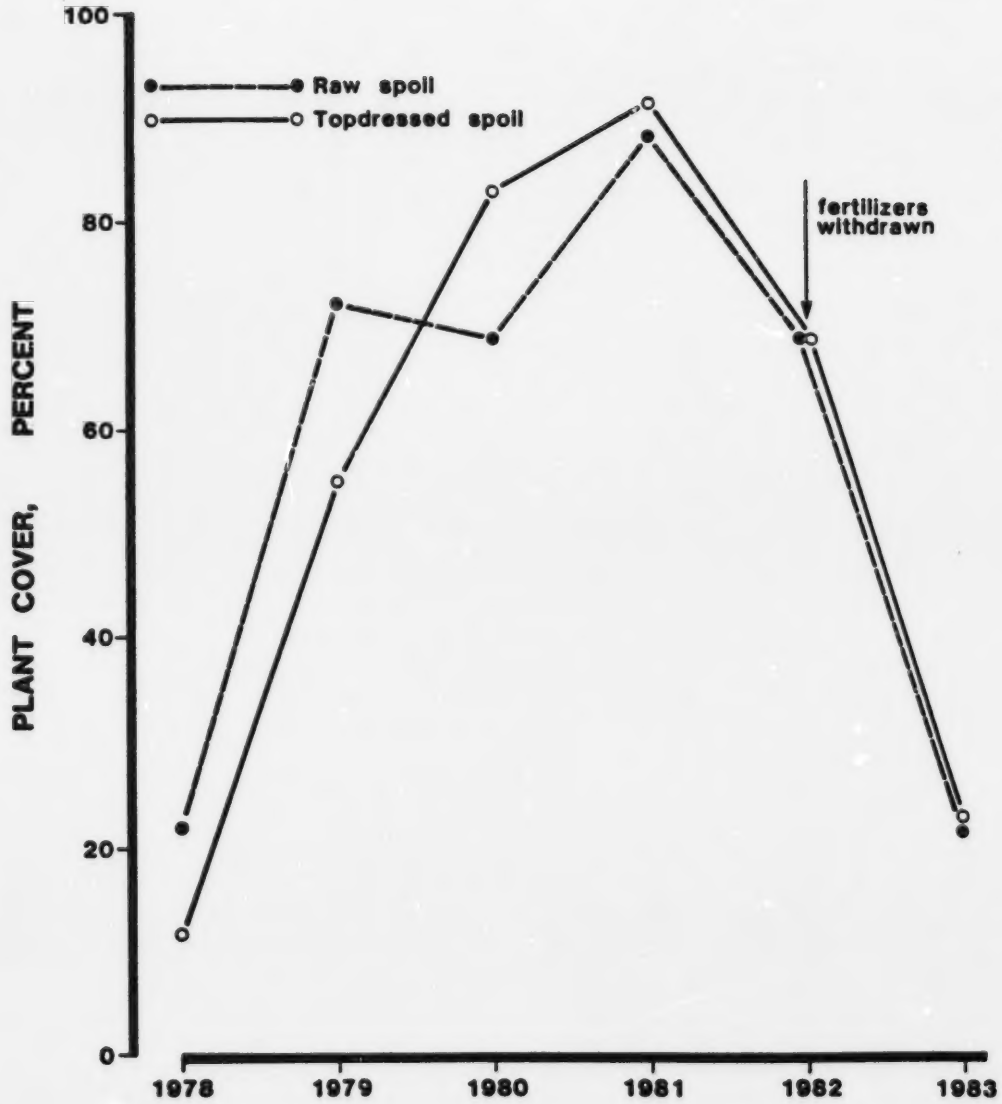
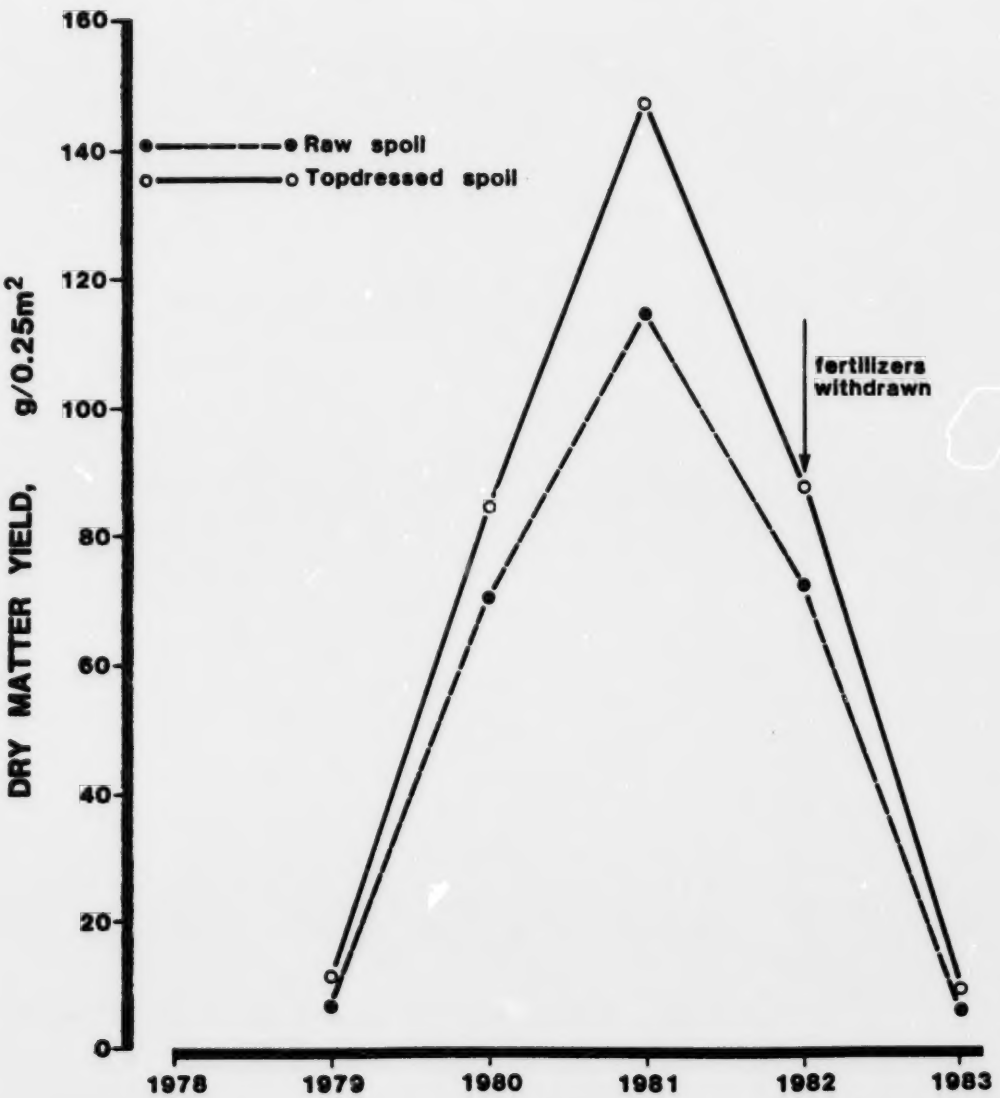


Figure 4: CHANGES IN DRY MATTER YIELDS BETWEEN SEEDING AND 1983 (TWO SEASONS AFTER FERTILIZERS WERE WITHDRAWN - FOR 60N-30P-60K Kg/ha.)



cover on the spoil suggests that the grasses and legumes assumed different growth forms (plant shape and height) on the spoil than on the topdressing material in the early stages of growth. Fertilization resulted in a considerable increase in the number of flowering tillers, especially with topdressing (Figure 5). This indicates that with the production of viable seeds the species in the seeded mix could more readily reseed themselves and increase the chances of revegetation success in subsequent years. Figure 6 indicates that by fertilizing or by topdressing there is a greater chance that all species in the seeded mix in a given a given area will survive and thus achieve a better species balance in the plant cover.

Native Grass Cover

Percentage of plant cover in the native grass mix was generally low in the first two growing seasons but by the fourth season (1981) cover had increased considerably, especially in the fertilized plots (Figure 7). Topdressing resulted in a much higher percentage of ground cover, especially if carried out in conjunction with fertilization. On the unfertilized raw overburden, the little plant cover developed in the first season had completely died out by the fourth season; on the unfertilized topdressed overburden, however, cover persisted and improved somewhat with time. Dry matter production levels in the fourth season (Figure 8) corresponded closely with the levels of percentage of plant cover. Table 3 shows the presence, expressed as frequency in percent of the seeded individual species in randomly selected areas

Figure 5: FERTILIZER INFLUENCE ON FLOWERING TILLER PRODUCTION AT THE END OF THE SECOND GROWING SEASON (1979)

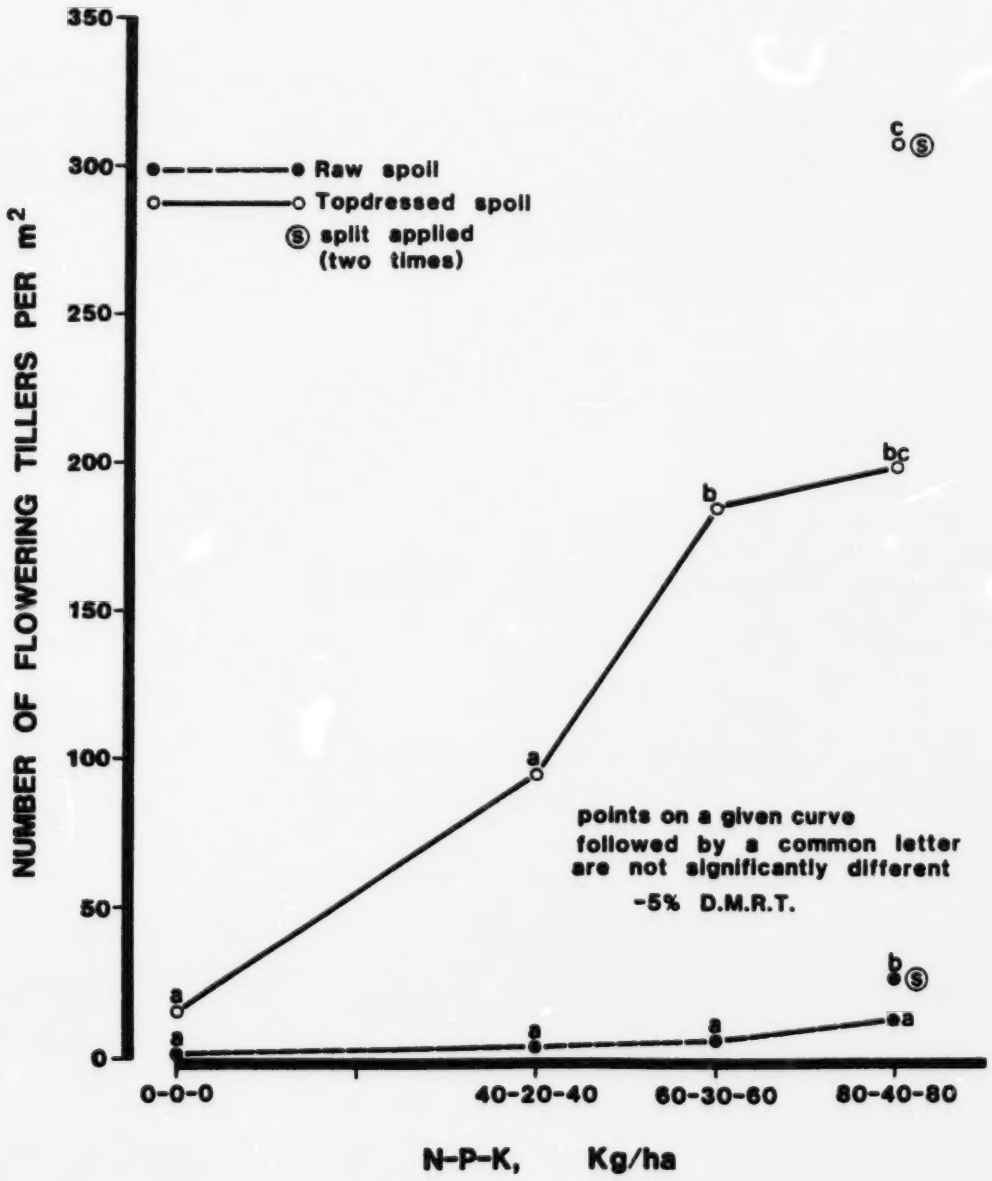


Figure 6: FERTILIZER INFLUENCE ON THE PRESENCE OF PLANTS OF ALL SEEDED SPECIES IN A GIVEN AREA (EXPRESSED AS A FREQUENCY PERCENT) AT THE END OF THE SECOND GROWING SEASON (1979) -60 Kg/ha SEEDING RATE

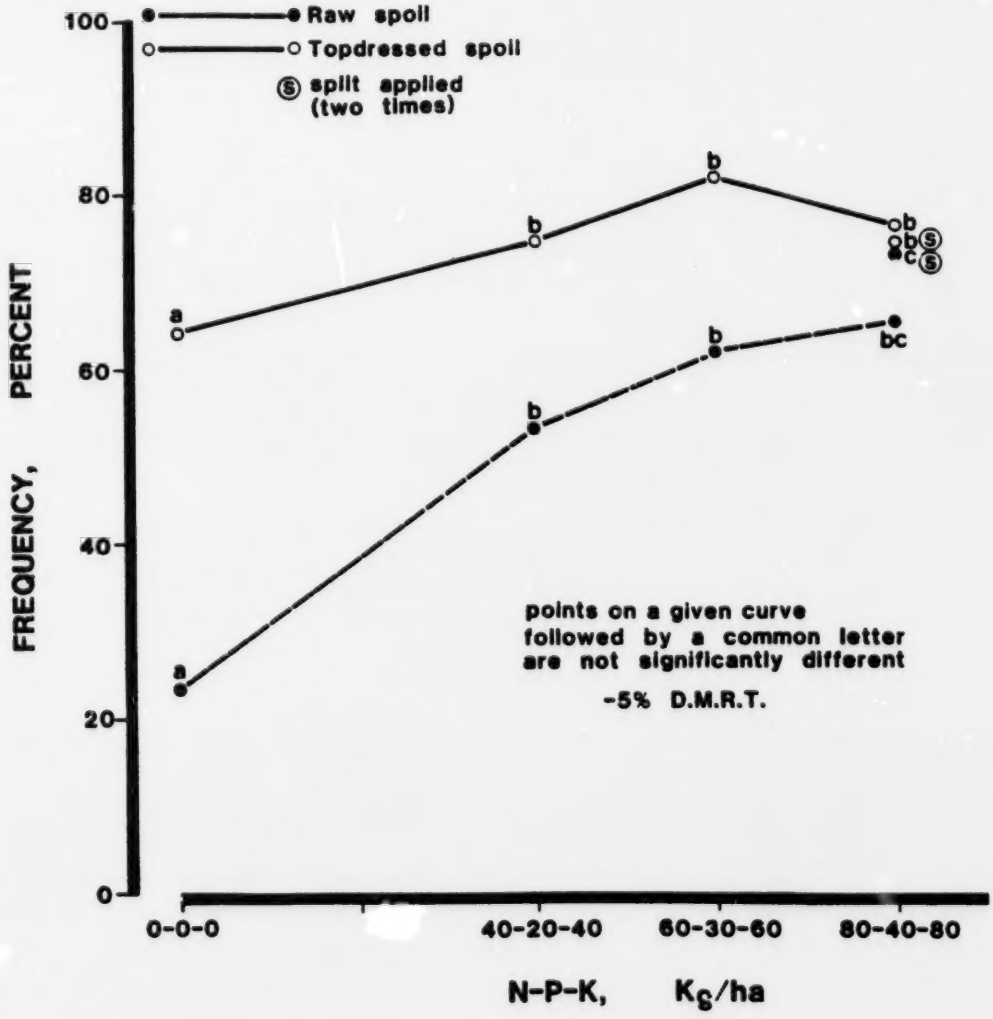


Figure 7: FERTILIZER EFFECTS ON PLANT COVER IN THE SECOND (1979) AND FOURTH (1981) SEASONS AFTER SEEDING NATIVE GRASS MIX - CADOMIN.

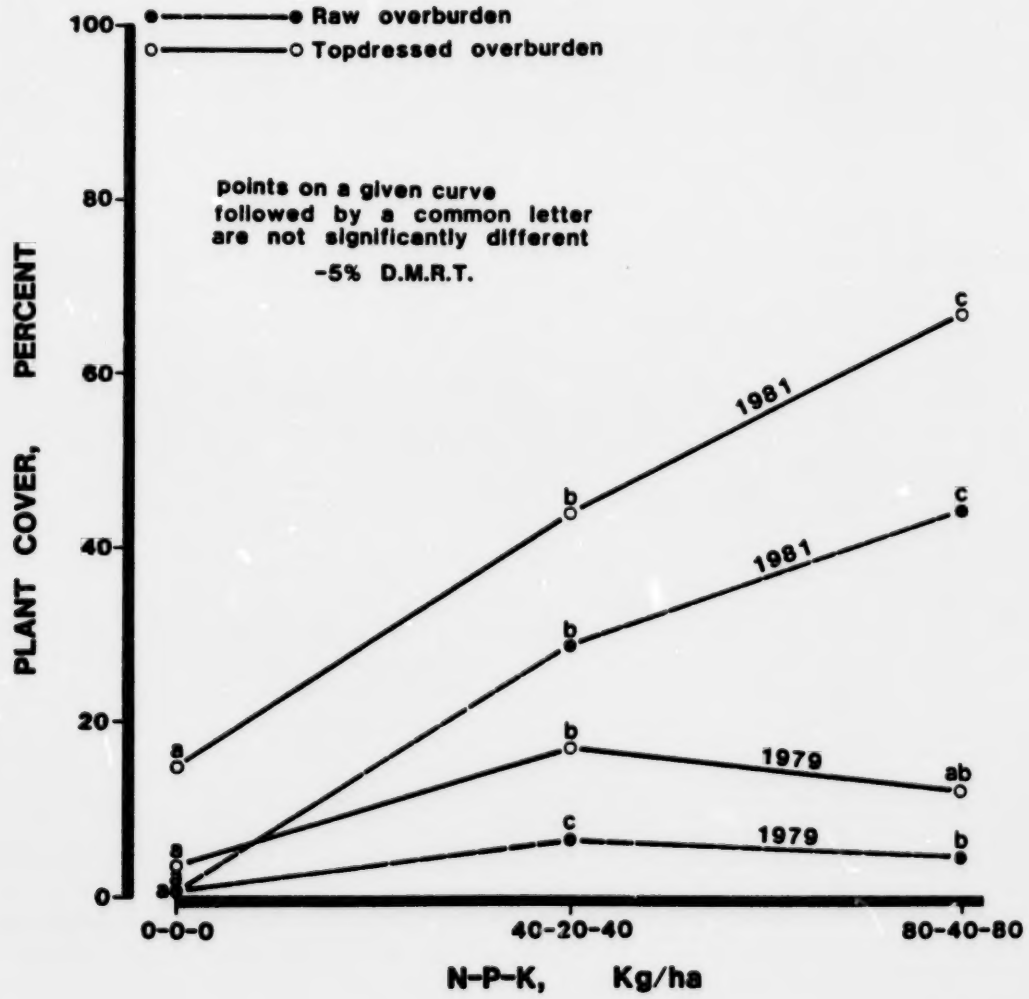


Figure 8: FERTILIZER EFFECTS ON DRY MATTER YIELDS PER PLOT IN THE FOURTH SEASON (1979) AFTER SEEDING THE NATIVE GRASS MIX - CADOMIN

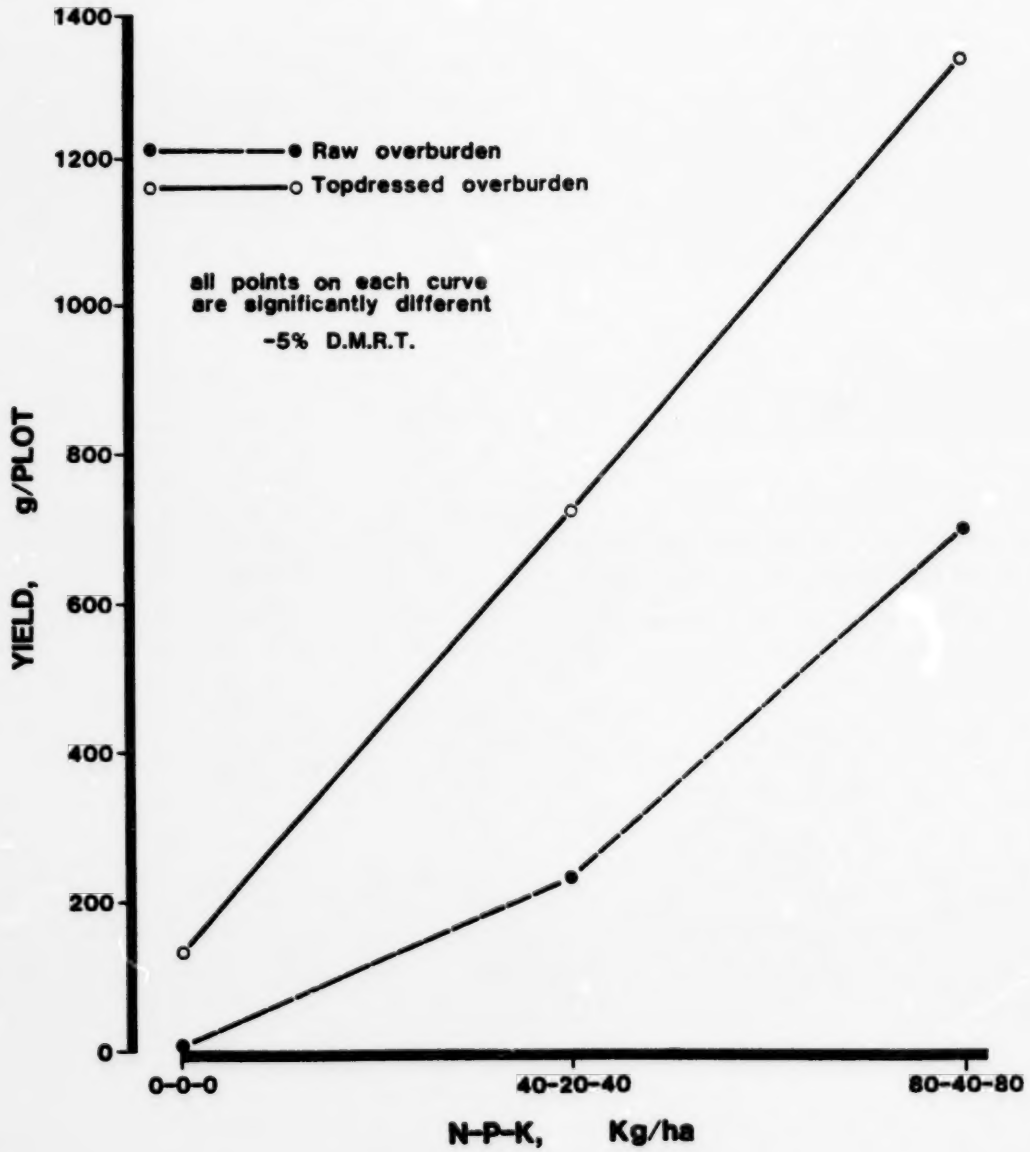


TABLE 3

FERTILIZER INFLUENCE ON THE MEAN SPECIES FREQUENCY (PERCENT) IN THE SECOND SEASON OF GROWTH OF THE NATIVE GRASS MIX* (1978 CADOMIN TRIAL)

	0-0-0	40-20-40	80-40-80
Raw overburden			
S_1 Agropyron trachycaulum	0	48	60
S_2 Festuca saximontana	27	23	31
S_3 Poa interior	0	8	10
S_4 Trisetum spicatum	0	0	2
S_5 (S_1 and S_4)**	0	2	13
Mean	5	16	23
	0-0-0	40-20-40	80-40-80
Topdressed overburden			
S_1 Agropyron trachycaulum	29	13	46
S_2 Festuca saximontana	31	8	25
S_3 Poa interior	23	4	21
S_4 Trisetum spicatum	2	0	8
S_5 (S_1 and S_4)**	6	0	2
Mean	18	5	20

* Treatment without companion crops - 1000 SEEDS m^{-2} seeding rate.

** Plants in this category were either S_1 or S_4 the two species could not be differentiated.

within the plots in the second season of growth. The results illustrate the advantage of fertilizers in achieving a more balanced species diversity on the raw overburden and clearly identifies Festuca saximontana as the species most likely to persist on sites which are very low in inherent fertility. (By the fourth season, 1981, all the plants in the unfertilized overburden plots had died.) Topdressing with a mineral soil appeared to be as effective as fertilizing the raw overburden in improving the distribution of the plants of the different species. Fertilizing the topdressed overburden did not appear to provide any advantage in the distribution of the species.

Generally, high fertilization of grass-legume mixtures results in diminished diversity in the species in the plant cover. For the conditions on the severe sites of the trials, however, fertilization of the raw overburden or spoil dramatically improved the diversity of the species in both the native grass mix and cultivated grass-legume mix.

One of the main reasons for the apparent preference for native grasses in revegetation is the expected low fertility demands on the soil. While the fertility demands may be low, the results of the fertilization trials indicate that native grasses, just as much as cultivated grasses, require certain minimum seedbed conditions, of which fertility is a very important component. Although both the native grasses and cultivated grasses and legumes seeded as companion crops in the unfertilized raw overburden plots germinated, nearly all plants which germinated in the first season eventually died. With the spreading of a mineral soil, which was also low in inherent fertility, over the overburden, some plant cover and dry matter production were achieved in the native grasses. Table 1

shows the mineral soil to be better than the raw overburden only in available P, total N, and total exchange capacity, and to have a more favorable reaction than the overburden. The increase in cover and production achieved by simply topdressing, or by applying 40 kg N, 20 kg P and 40 kg K/ha, confirms that at least on severe mine overburdens which are also low in fertility some fertilization is necessary to achieve a native grass cover.

Companion Crop Effect

The influence of companion crop treatments on the establishment and growth of native grass mixtures in high-elevation harsh environments is summarized in Figures 9 and 10, and in Table 4. Figures 9 and 10 show the results of the trials established at Cadomin in 1978 with one native grass mixture, and Table 4 shows the means for the 1979 trials with four different native grass mixtures at Cadomin and Adanac. In the 1978 trials, the results, because of the companion crops on the overburden, show no advantage in percentage of plant cover or dry matter production up to the end of the fourth growing season. The only advantage to companion crop treatment on the topdressed trial occurred in the fourth season, and this was due primarily to the role played by the cultivated perennial grasses and legumes which still persisted. The red clover in the other companion crop treatment had essentially died out.

Results of the trials which were established in 1979 (Table 4) also showed no significant advantage in percentage of plant cover due to companion crops by the end of the 1980 growing season at Adanac and

Figure 9: COMPANION CROP EFFECTS ON PLANT COVER IN THE SECOND (1979) AND FOURTH (1981) SEASONS AFTER SEEDING A NATIVE GRASS MIX - CADOMIN.

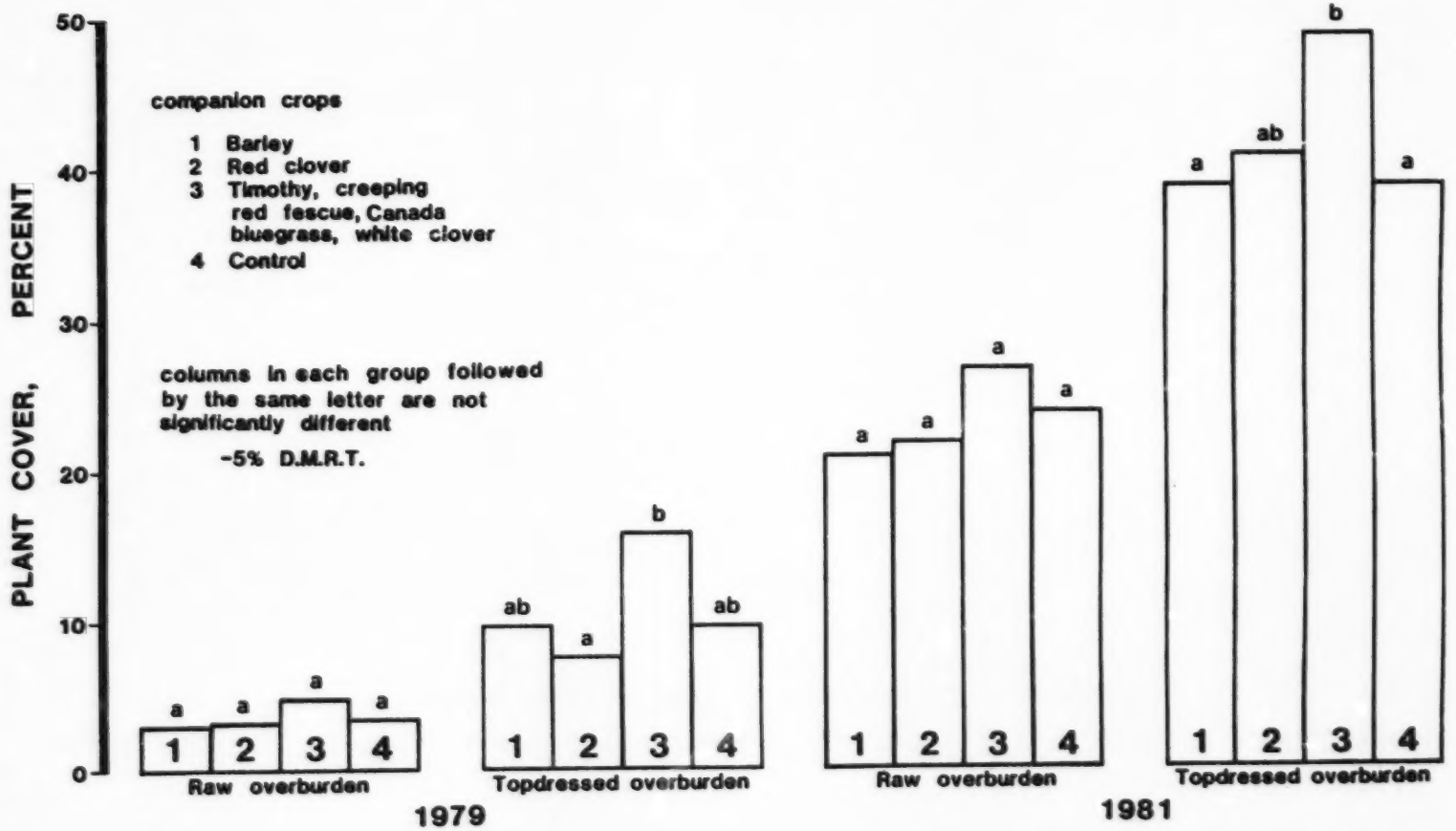


Figure 10: COMPANION CROP EFFECTS ON DRY MATTER YIELDS IN THE FOURTH SEASON (1981) AFTER SEEDING A NATIVE GRASS MIX - CADOMIN.

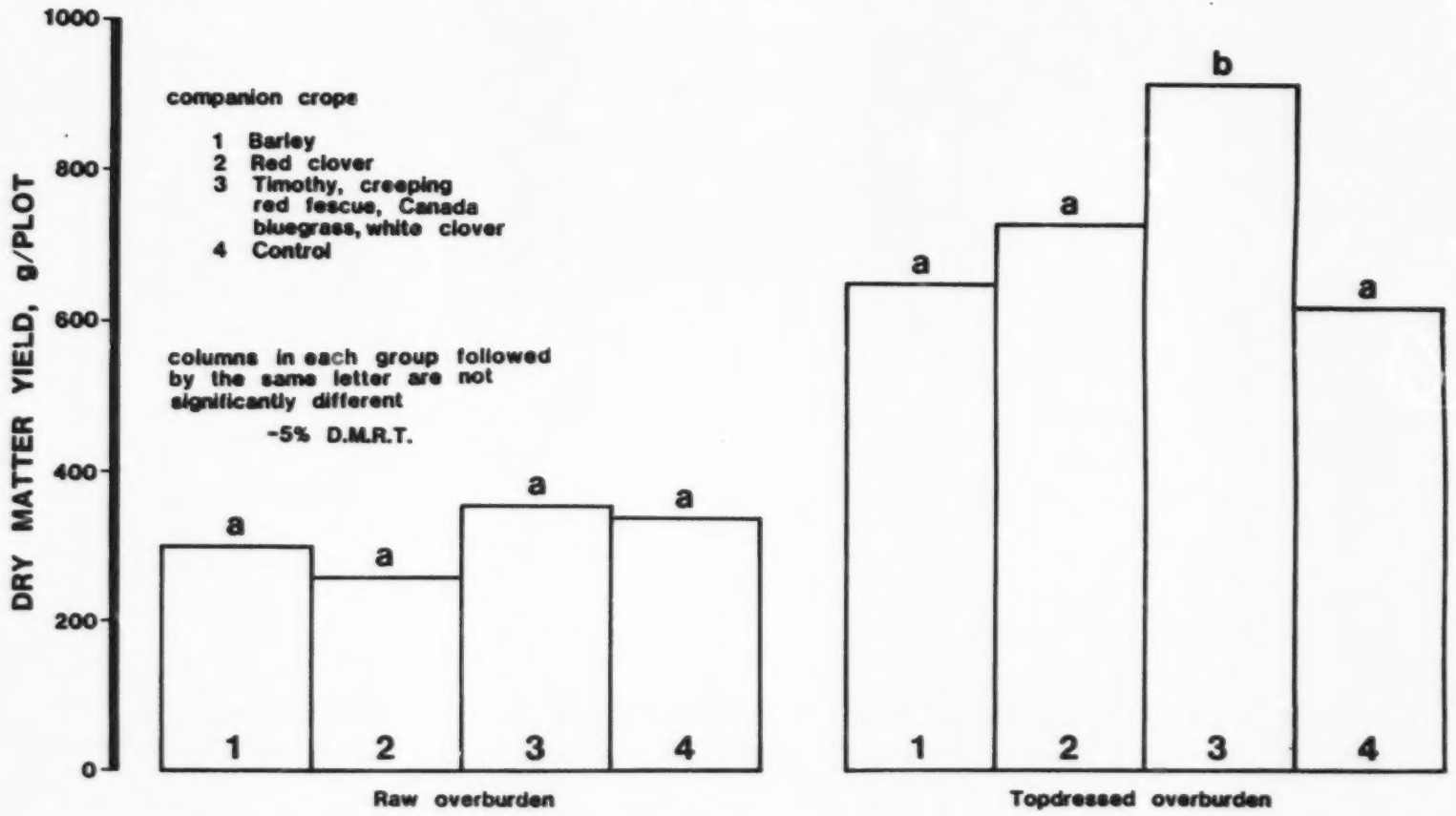


TABLE 4

MEAN INFLUENCE OF CULTIVATED COMPANION CROPS ON PERCENT PLANT COVER PRODUCED IN FOUR DIFFERENT NATIVE GRASS MIXTURES* AT THE END OF THE 1980 GROWING SEASON (SEEDED IN 1979) — After Tomm and Russell, 1981.

	COMPANION CROPS **				
	MF	T + WC	CRF + AC	PR	C
CADOMIN					
Raw overburden	9.2	13.1	12.4	14.6	11.6
Topdressed overburden	28.7	24.5	24.0	23.5	19.0
ADANAC					
Raw overburden	33.7	35.7	30.0	30.3	25.2
Topdressed overburden	36.3	27.0	22.8	24.0	20.2

* Mean of 4 native grass seed mixtures in 3 replications
Companion crop treatments differences in a given row are not significant

** MF = meadow foxtail; T + WC = Timothy and white clover;
CRF + AC = creeping red fescue and alsike clover; PR = perennial ryegrass; C = control.

Cadomin. The controls, however, generally gave lower percentage of cover as compared with the companion crop treatments. The reason for the lack of significance in the companion crop effect on cover is that in the early stages of plant cover establishment any competitive effects of the cultivated grasses and legumes on the native grasses are minimal. Results of the 1978 trials at Cadomin suggest that competitive dominance of the native grasses is possible in later stages of cover development and that some companions crops significantly influence cover by the native grasses. The trials clearly show, however, that in the first few seasons of growth companion crops offer no significant advantage in cover establishment with native grass mixtures. In general, production was greater with topdressing as compared with no topdressing; the lower plant cover with topdressing at Adanac is attributable to the higher seed and soil losses following seeding caused by wind erosion, as compared with the raw overburden on which losses were estimated to have been minimal.

The influence of the companion crops on the relative presence and distribution (expressed as percent frequency) of the native grass plants in the plots are given in Table 5 for the 1978 trials. Barley and red clover as companion crops had died out, and the grass-legume mixture still persisted by the end of the second growing season; however, the frequency of the native grasses in the grass-legume companion crop did not differ much from that of the control or any of the other treatments. The comparatively high percentage of native grasses, even with the highly competitive cultivated companion grasses and legume mix as

TABLE 5

MEAN COMPANION CROP INFLUENCE ON INDIVIDUAL NATIVE GRASS SPECIES FREQUENCY (PERCENT) AT THE END OF THE SECOND GROWING SEASON (1979) AT CADOMIN

	BARLEY	RED CLOVER	MIX *	CONTROL	MEAN
Raw overburden					
S_1 Agropyron trachycaulum	35	38	38	35	37
S_2 Festuca saximontana	38	41	39	40	40
S_3 Poa interior	6	10	7	8	8
S_4 Trisetum spicatum	1	0	0	1	1
S_5 (S_1 and S_4) **	5	3	3	6	4
Mean	21	23	22	23	22
(Companion Crop)	(0)	(0)	(33)		
Topdressed overburden					
S_1 Agropyron trachycaulum	50	51	51	49	50
S_2 Festuca saximontana	41	42	39	37	40
S_3 Poa interior	34	30	27	30	30
S_4 Trisetum spicatum	8	7	6	9	8
S_5 (S_1 and S_4) **	6	5	5	6	6
Mean	35	34	32	33	34
(Companion Crop)	(0)	(1)	(88)		

* Timothy, creeping red fescue, Canada bluegrass and white clover.

** Plants in this category were either S_1 or S_4 the two species could not be differentiated.

compared with the other treatments, again may suggest that, at least in the early stages of growth, native grasses are able to compete favorably with cultivated species.

CONCLUSIONS

The trials discussed in this paper have identified the need for a minimum soil fertility requirement for grasses in the revegetation and rehabilitation of severe land disturbances in alpine and subalpine environments. This minimum requirement applies equally to native grass mixtures and cultivated grass-legume mixtures grown on unamended mine spoil or overburdens inherently low in the essential plant nutrients.

In these trials, plant cover establishment failed in both cultivated and native grass mixtures on the raw overburden or spoil. Topdressing resulted in some improvement in cover establishment and biomass production, and fertilizers always assured cover establishment success. Fertilization increased the number of flower-bearing tillers in the cultivated grasses and thus improved the chances of seed production for the eventual filling in of the bare areas of the plots. Fertilization also improved the chances of achieving a mixed-species plant cover, as opposed to a poor cover of one species which may be fairly tolerant of low soil fertility. This observation appears to contradict the widely accepted fact that high fertilization of grass-legume mixtures results in diminished diversity of the species in the plant cover. In general, topdressing with a mineral soil may be considered an alternative to fertilization if the inherent native fertility meets a critical requirement.

Native grasses apparently have a lower soil fertility requirement than cultivated species. The results of these trials show, at least for the severe environments of these trials, that if cultivated grasses do not grow because of poor soil fertility, we should not expect the native grasses to grow any better.

Native grasses have been expected to be better plants for revegetation of alpine and subalpine areas than introduced species, because native plants are known to be better adapted climatically and therefore more capable of surviving in the severe sites. Experience, however, shows that plant cover in the first season of growth in alpine and subalpine regions is at best minimal in most cases with native grasses. In situations where site stabilization in the shortest possible time is the primary objective, native grass usefulness may be greatly diminished. For this reason, the use of faster-growing cultivated species as companion crops to the native grasses strikes an appeal. Results of the six trials, three on overburden and three on topdressed overburden, generally gave the same percentages of plant cover levels and dry matter production with companion crops as with the control on the raw overburden. In the second season of growth on the topdressed overburden, companion crop treatments gave generally higher, but not significantly higher, percentage of plant cover than the control; by the fourth season of the trials started in 1978 only the cultivated grass-legume companion crop mixture had given a significantly higher dry matter production than the control.

In general, on these severe sites in the alpine and subalpine regions, it could be concluded that companion crops made up of cultivat-

ed grasses and/or legumes proved to be of little benefit to the successful establishment of native grass cover in the early stages of growth, whereas normally the fast-growing cultivated species establish more rapidly to stabilize the ground surface. The companion crops did not appear to have influenced the relative presence and distribution of the native grasses in the established plant cover at the end of the second growing season.

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POOR

QUALITY

ORIGINAL